Comparison of environmental life cycle analysis of aluminium alloy (LM 6) street light housing and aluminium alloy (AL Si12Cu1{Fe}) housing

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COMPARISON OF ENVIRONMENTAL LIFE CYCLE ANALYSIS OF ALUMINIUM ALLOY (LM 6) STREET LIGHT HOUSING AND ALUMINIUM ALLOY (AL SI12CU1{FE}) HOUSING

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ABSTRACT

The environmental impact of the re-manufactured aluminium alloy (LM6) street lamp has been analysed. The results have been compared to the new housing lamp made of aluminium alloy (Al Si12Cu1{Fe}). The methodology used to calculate life cycle inventory and environmental impact is BEES V4.07 and Ecoinvent V3 was used as reference since it is the most updated database. The results show that the reworked aluminium lamp has an environmental impact of 2.38 pts and compared to that of alloy (Al Si12Cu1{Fe}) which has an impact of 2.56 pts. The first major factor is that the housing remanufacturing process does not consider the primary production processes of mining, extraction and casting. The new housing includes the primary production processes and casting thus impacting heavily on the environment. The second major factor that contributes to the lower impact of the remanufactured housing than the new housing is the low energy use since the housing is not remanufactured by re-casting which is basically a re-cycling process.

Keywords: life cycle analysis, aluminium housing, light emitting diode, high pressure sodium.

1. INTRODUCTION

This study aims to determine the environmental impact of two street light aluminium housings. One City Council in UK is to embark on a project to replace high pressure sodium (HPS) street lights with light emitting diode (LED) street lights. This is due to the high energy consumption of the old lights. It is estimated that the replacements will make savings in energy, carbon emissions and maintenance among others [1].

Environmental benefits can be comprehensively assessed using life cycle analysis (LCA). Environmental impact assessment of a product considers the whole life of the product from cradle to grave. It is the way the product impacts on the ecosystem or environment through production to disposal that can then be judged as friendly or not. This assessment method has become popular in recent years due to the holistic approach to environmental assessment [2].It quantifies the level of impact on the environment.

Aluminium contributes 3% of total global carbon emissions for material productions.[3]. Thus any reduction in aluminium material production would result in significant cuts in carbon dioxide emissions and in the environmental impact in general. Additionally, reduction in aluminium material production can also be achieved by alternative production such as recycling, re-use and remanufacturing. Remanufacturing is therefore one of the mean to be considered in order to reduce the environmental impact of a product. Environmental impact of aluminium and aluminium products is also affected by the alloying of the aluminium material. The environmental impact of aluminium alloying elements composition differs significantly [4].The alloying elements that create the highest environmental impact are copper, silicon and tin, elements which are commonly used in aluminium alloys. Material composition has to be taken into consideration when product environmental impact.

Recycling scenarios using LCA have been analysed on LED lighting aluminium housing produced by Zalux [5]. The housing and mechanical components were taken into account. The analysis focused on the material selection process and the end of life of the mechanical parts. The electrical components were not considered in the analysis. Products that are similar in major material terms and functionality (eg. LEDs) may have different environmental impacts based on the other components in the assembly such as connectors and driver circuit [6].

This study aims to quantify the environmental impact of a remanufactured aluminium alloy street light housing and compare the results to that of a different new aluminium alloy street lighting housing. ISO standards 14040 and 14044 of LCA have beenapplied. It is to provide information on which product is environmentally friendly and assist in making a decision. The LCA is however not part of a decision making process but assists in decision making [7].

2. LCA METHODOLOGY

2.1. Product Structure

The methodology in this study has been chosen base on the products structures the old lamp has a different structure and composition from the new one. The product structures and differences are shown in the figure 1

After remanufacturing the old lamp the structure will change. The electrical components will be replaced by an LED module similar to the one in the new lamp. This change has a very significant effect on the environment and hence cannot be ignored in the analysis. Thus the replacement of the bulb and holder, cables, capacitor, igniter, ballast and plastic parts will have an effect on the environment because of their end life and consequently the waste scenarios. The new LED comes complete with LED module and housing. Figure 1 shows the old lamp structures of the two products.

2.2. System Boundaries

In LCA, it is traditional to analyse the product from cradle to grave. In this study the interest is on the impact of the remanufactured housing. The new LED which is being compared with is being procured as a complete product. Therefore, the products have different boundary specifications. The remanufactured housing does not have the raw materials extraction considered. The new LED assembly have the upstream processes considered. The downstream stages of use and end life have not been considered. Figure 1 shows the production sequence for the remanufacture housing.

2.3. Life Cycle Inventory (LCI)

2.3.1 Modelling Scenarios

In order to model a product LCA the LCI has to be established. The input data was collected about the old housing and the new lamp. The old housing data includes the housing and the electrical components. Electrical components for the old lamp are replaced by the new LED lamp and the associated circuits. Below are the modelling methodologies which have been used.

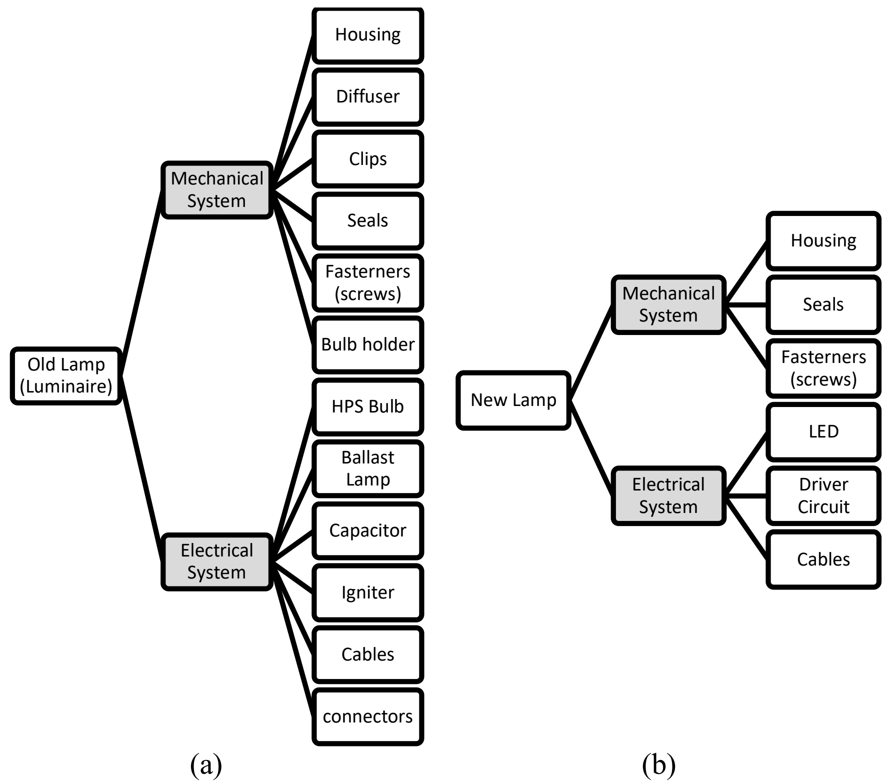

Figure 1: Product Structure (a) Old HPS lamp (b) New LED Lamp

(i) Scenario 1: Replacing the old housing with a new one

In this model the old lamp is completely replaced by the new lamp. This means the new lamp environmental impact is composed of the new aluminium housing, the LED lamp, the associated circuit, the old housing, the old lamp (HSP bulb) and the associated electrical. The input data therefore comprises for both lamps. Table 1 shows the inventory for the new lamp. Data for each component for the old lamp was obtained by weighing and material identification.

Table 2: New Lamp Inventory[8]

Part	Component	Mass (kg)	Part	Component	Mass (kg)
Capacitors	Ballast	0.06	**Housing (polypropylene)**	Ballast	0.808
Zener diodes	Ballast	0.0012	**PET fi**	Ballast	0.046
Resistors	Ballast	0.12	**Base**	Ballast	2.52
Integrated circuit	Ballast	0.24	**Metal clips**	Fitting	0.692
Transistor	Ballast	0.036	**Wiring**	Fitting	0.231
Foam	Ballast	0.069	**Copper pins**	Fitting	0.0023
Inductor	Ballast	0.072	**Base contacts**	Lamp	0.009
Inductor	Ballast	0.048	**Base contacts**	Lamp	0.005
PCB (Al. machined tooled block)	Ballast	4.615	**LED**	Lamp	0.36
Wiring	Housing	0.046	**Glass**	Lamp	0.96
Solder paste	Ballast	0.023	**Coating**	Lens	0.012

Housing	Housing	0.84	**Coating**	Lens	0.012
Card	Packaging	0.069			

(i) Scenario 2: Remanufactured Old Lamp

In this model the old lamp is remanufactured. The major remanufacturing activities are disassembling, coating and assembling. In the disassembling all electrical components are removed and form part of waste which is handled differently. In the assembly process, the housing is fitted with new LED lamp and the associated circuit (ballast). Therefore the inventory for the remanufactured lamp includes the old housing, polyester, and the LED lamp and its associated electronics. The other part of LCI are the impact elements. These are the outputs from the analysis. They are obtained by characterisation. The output inventory is a comprehensive list of 1496 impact elements.

3. ENVIRONMENTAL IMPACT ANALYSIS

The impact elements are allocated to areas of impact. The analysis tool used is SimaPro 8.4. The impact assessment method is BEE+ V4.07. The impact category areas assessed are global warming, acidification, human health, eutrophication, ecotoxicicty, photochemical smog, natural resource depletion, habitat alteration, ozone depletion and water intake

3.1. Results

3.1.1. Scenario 1:

Replacing the old lamp with a complete new one has a normalized overall impact of 2.59 pts (Figure 2). On a single score analysis, the also shows that eutrophication category is heavily impacted and the LED electronics are the major contributors (figure 2). It contributes 85% o the total impact.

1.1.1. Scenario 2

Remanufactured housing and fitting with new LED shows an overall impact of 2.194 pts The most impacted category is eutrophication and the major contributing component is the LED and associated circuit (figures 3).

2. DISCUSSION

2.1. Comparisons

Comparison of the two products shows that the New LED lamp has a higher impact in all categories than the remanufactured lamp. The new LED lamp has 0.366 pts more impact than the remanufactured lamp. This is due to the re-use of the old aluminium.

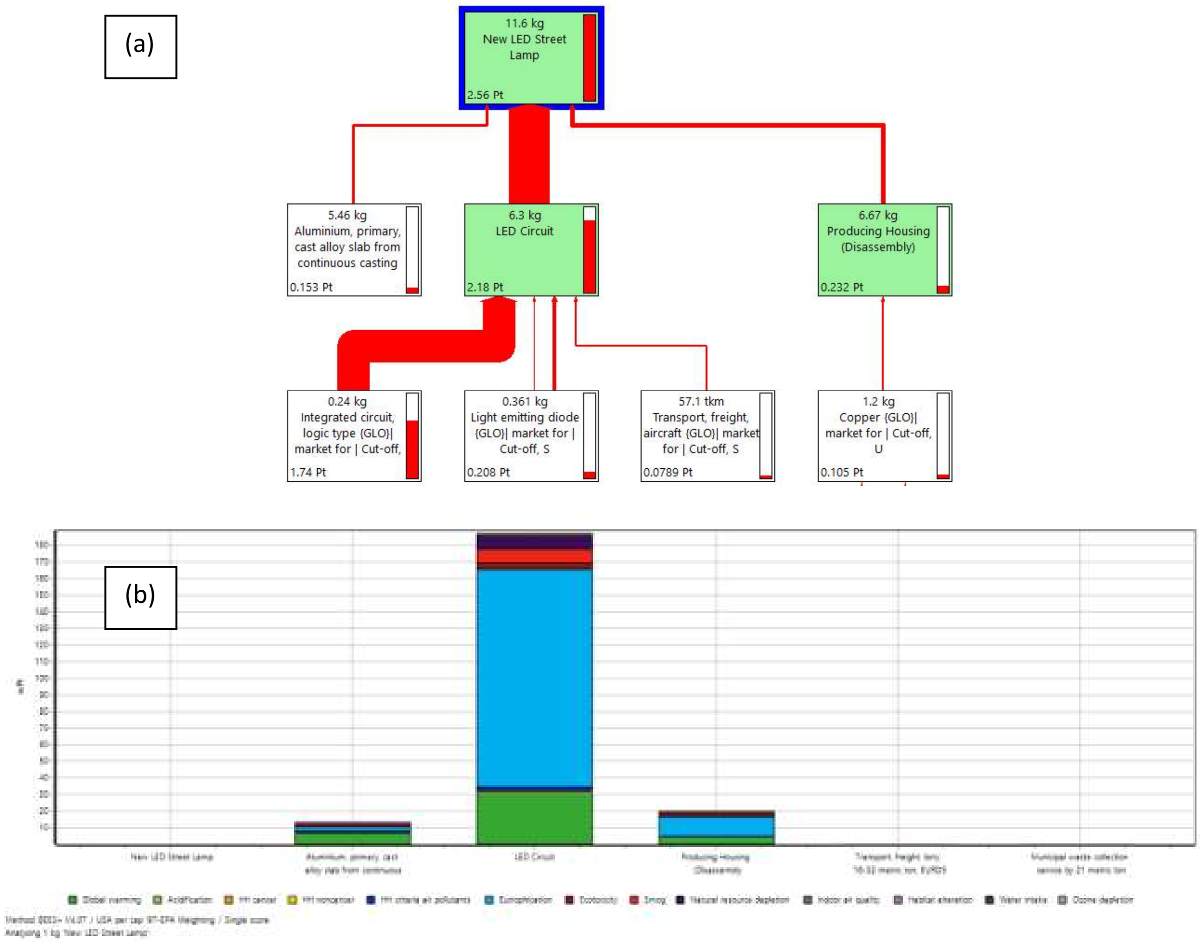

Figure 2: New Lamp Overall Impact (a) Process contribution (b) Single Core Contribution

In both cases it has been observed that the major contributing factor to the environment is the use of the new LED lamp with its associated electronics; the driver circuit in the lighting. The changes that are effected on the remanufactured housing do not have much impact on the environment unfriendly. The LED data is based on global factors. This is a generalised weakness because different countries have different impacts due to electricity mix among other factors.

The remanufacturing of the old lamp has little impact. The fact that the manufacturing process does not involve change material mass such as machining. Machining would mean using more energy and generating waste material. The processes do not include smelting which would also contribute to high energy use. The major factor that may have contributed to the increase in environmental impact of the remanufactured housing is the coating process. This is because it is the major difference between the two products. In both cases it is observed that the electronics have a major contribution to the environmental impact. This confirms the fact that the manufacturing of semiconductor products has a very high impact on the environment. It shows that the older high pressure lamp should not be replaced by the LED. However the LED lamp has a much bigger advantage over other lighting technologies in the use phase. Thus the LED would still be fitted even in the remanufactured lamp.

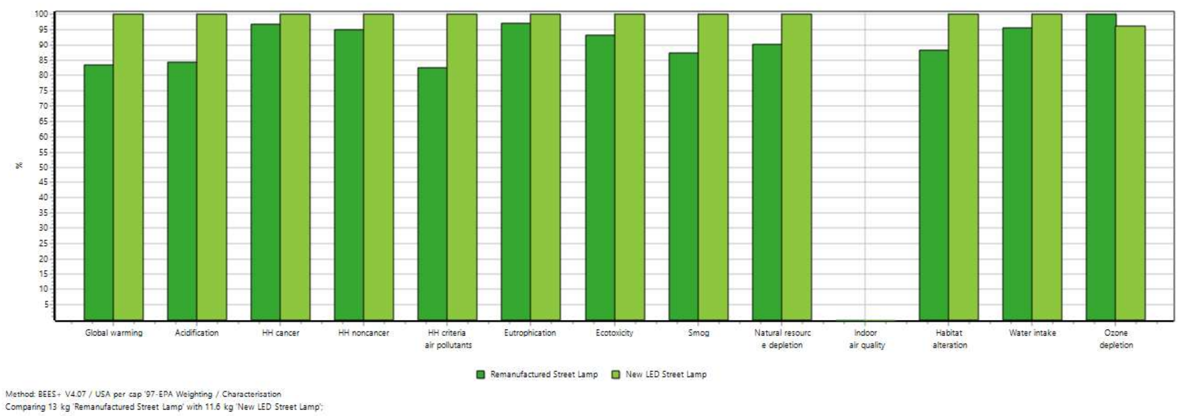

Figure 3: Characterization Comparison of New Lamp and Remanufactured Lamp

3. CONCLUSIONS

The study has shown that the remanufactured lamp has a lower environmental impact than the new lamp. Replacing it completely makes the new lamp to have a much higher environmental impact. The study has also shown that remanufacturing a product is environmentally friendly. Usually for a decision to remanufacture a product is reached based on comparison with other products. An LCA should be carried out for the remanufactured product and compare it with the other competing products. This study shows that comparison should also include environmental impact. The remanufacturing processes should be carefully be analysed and a decision made not only based on economic benefits nut also on environmental impact basis. Remanufacturing is therefore a serious option to consider when replacing a product in order to reduce product environmental impact.

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